Column Study for Evaluation of In-Situ Iron Fouling... A Cautionary Tale of Aquifer Blockage

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Hydrocarbon impacts to groundwater are commonly observed at rail sites due to derailments, historical fueling practices or spills during loading and unloading of railcars. An excess of hydrocarbons added to the subsurface provides a readily available energy source for native microorganisms which subsequently scavenge and deplete available electron acceptors (e.g. oxygen, nitrate, ferric iron, manganese, sulfate, and carbon dioxide) and drive the groundwater to anaerobic and reducing conditions. These conditions transform naturally occurring redox-sensitive metals such as iron and manganese to their more reduced and soluble states; which become mobile in the groundwater creating dissolved metals plumes that shadow the hydrocarbon plumes.

Addition of oxygen into the subsurface via a number of methods including oxygenated water injection, air sparging and injection of oxygen releasing compounds is a common method for stimulating aerobic biodegradation of the hydrocarbons. An often overlooked side effect of oxygen injection into the subsurface is that shifting the aquifer geochemistry back to aerobic conditions will cause redox sensitive metals such as iron and manganese to precipitate back out of solution as metal oxides or hydroxides. The rapid precipitation of labile metals can cause reductions in the aquifer pore space and diminished injectability of the aquifer, which can decrease the overall effectiveness and increase operational attention of remedial systems that require multiple aquifer pore volume exchanges. If reduced metals are present in sufficient concentrations at a site, the aquifer can become totally occluded which can render high cost active remedial systems useless and make alternative means of plume remediation more difficult.

This presentation will detail a bench-scale column study performed using intact soil cores collected from a site being evaluated for directed groundwater recirculation, which would have required long-term re-injection of aerobic groundwater to an aquifer with reducing conditions. Six columns were tested using a combination of aerobic and anaerobic water and a conservative bromide tracer. The total number of pore volumes moved through each column and the sustainable injection rate were evaluated to characterize the extent of aquifer clogging anticipated after full-scale remediation was initiated.

Results showed a rapid decrease in the achievable flow rate of a column purged with aerobic (~8 milligrams per liter [mg/L] dissolved oxygen) water, which eventually led to complete clogging due to metals precipitation. Conversely, the tests run using columns purged with anaerobic water showed no decrease in flow rate and an indefinite number of pore volumes flushed through the core. The system, now in operation, uses a modified design to scrub oxygen prior to injection. The study, applicable to any rail site considering long-term injections of aerobic water into a reduced aquifer, was the key factor in steering remedy development and their applicability for the site.